# A STUDY OF AIR ABSORPTION OF SOME LIQUIDS

By G. L. DE and P. MAHANTI
Dielectric Research Laboratory, Department of Applied Physics,
Calcutta University.

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**ABSTRACT.** A study of the air absorption characteristics of some liquids gives an idea of the stability, degree of polarity and the quality of the liquids under investigation. An empirical relation is also attributed.

## INTRODUCTION

It is well known that the gas absorption of insulating liquids is one of their important physical properties and it plays a very important role so far as their electrical properties are concerned. In fact, an ordinary non-degassed liquid suffers a huge change in its physical, chemical and in electrical properties when it is subjected to the process of degassing. The gas absorption of a particular insulating liquid is an effective agent in determining its dielectric strength. Clark (1935) observed that the relation with temperature for both air absorption and dielectric strength of an insulating oil were similar in nature. He also found that the effect of temperature and pressure on the dielectric strength of an insulating liquid is a logarithmic function of the relative density of the dissolved gas. In fact the absorbed air within an insulating liquid forms gas-pockets; due to insipient discharges during an increased voltage stress they form easy seats for ionising centres, thus leading to a heavier conduction current and a premature break-down of the liquid. The oxygen in the dissolved air has a deleterious effect on the chemical structure of the liquid and consequently is responsible for an increased polarization and power-factor. The electrical conduction in a highly refined liquid may be taken as obeying the corresponding laws for gases, and Nikuradse (1932) showed that the behaviour of such a liquid in the current voltage relation corresponds to that of a gas. Organic liquids have a tendency to acquire an increased dielectric constant when bubbled with air, due to the polarization of the carbon molecules by oxydation. Sisskind and Kasarnovsky (1937) examined a most interesting relation between electric polarizability, dipole moment and solvent power. In fact insulating oils are graded according to their gas absorptive power for their relative suitability as insulants in different service requirements.

In view of the importance of gas absorption in liquid dielectrics, investigation of this property was undertaken with special reference to insulating oils, vegetable oils being the centres of interest. When specially refined

and processed, vegetable oils are expected to work as good substitute for their mineral and synthetic relatives. Properties of some of the vegetable oils in raw and unprocessed condition were studied previously by Bhattacharya (1936, 1937) and Ghosh (1940). The works of several other investigators viz., Paranjpe and Deshpande (1934-35), Mahanti and Chakrabarty (1942) can be mentioned in this connection. Attempt was here made to study the nature of absorption of a few vegetable oils in their refined stages. Distilled water and transformer oil were also included in the list for investigation, as standards for comparison. The following liquids were used for investigation purposes: (1) Distilled water, (2) transformer oil, (3) linseed oil, (4) groundnut oil and (5) sesame oil.

## EXPERIMENTAL

(a) *Preparation of sample*:

Redistilled conductivity water was used in the present investigation. The oils were carefully refined in the laboratory. Firstly a specimen of the oil was washed with a definite strength of lye solution and after separating the soap it was washed again with a lye of higher strength and the process repeated till the acid number was as low as possible. Finally the oil obtained was treated with 5% of its weight with Fuller's earth and sufficient quantity of silica gel. All such treatments and washing were performed at an elevated temperature of about 50°—60°C. The oil was then filtered under fine filter paper and its acid number tested as usual with standard KOH solution. The sample was then ready for absorption measurement.

(b) *Measurement technique*:

The measuring apparatus was the same as used by Bhattacharya (1936, 1937) but the technique of measurement was a little modified. The liquid under investigation was degassed for four to five hours and as the temperature of the liquid was lowered due to degassing, it was kept at rest for some time to attain temperature equilibrium. Air was let in and the absorption process commenced when the flask was shaken. Throughout the absorption process the mercury menisci were always kept to the same level in the manometer limbs, so that the pressure of air inside the flask was always constant. The experiment was continued for sufficient time so that equilibrium conditions were attained regarding absorption.

## RESULTS

The experimental data are given in Tables I—V. For a comparative study absorption of air per c.c. of the liquid was considered and the experimental temperature and pressure were reduced to N.T.P. Volume per cm. of the manometer tube was found to be 0.162861 c.c. and the samples having acid number greater than 0.17 mgm. of KOH/gm. of oil, were rejected.

TABLE I. Distilled water

Experimental conditions: Volume taken—70 c.c, temperature —32.8°C, initial level —6.0 cm, degassed for 4 hours.

$\alpha_0 = 0.02202$. $\lambda = 0.3$.

| Time interval minutes | Mercury level in manometer cm. | Length of mercury column cm | Absorption per c.c. $\alpha_{obs.}$ c.c.) | Absorption per c.c $\alpha_{cal}$ (c c.) |
|---|---|---|---|---|
| 1 | 17 5 | 11 5 | ·0.02389 | 0.02121 |
| 3 | 17.5 | 11.5 | 0 02389 | 0.02202 |
| 8 | 16 6 | 10.6 | 0.02202 | 0 02202 |
| 12 | 16.6 | 10.6 | 0.02202 | 0 02202 |
| 17 | 16.55 | 10.55 | 0.02192 | 0.02202 |
| 22 | 16.55 | 10.55 | 0.02192 | 0.02202 |
| 27 | 16.35 | 10.35 | 0 02149 | 0 02202 |
| 47 | 16.35 | 10.35 | 0.02149 | 0.02202 |

TABLE II. Transformer oil.

Experimental conditions: Volume taken—49.95 c.c, temperature—25.1°C. initial level—4.65 cm. degassed for 4 hours.

$\alpha_0 = 0.09428$. $\lambda = 0.87$.

| Time interval. mins. | Mercury level in manometer cm. | Length of mercury column cm. | Absorption per c.c. $\alpha_{obs.}$ (c.c.) | Absorption per c.c $\alpha_{cal.}$ (c.c.) |
|---|---|---|---|---|
| 2.10 sec | 33 7 | 29.05 | 0.08678 | 0.08654 |
| 3 30 ,, | 35.9 | 31.25 | 0.09335 | 0.09255 |
| 4.40 ,, | 36.0 | 31.25 | 0.09364 | 0 09386 |
| 7.30 ,, | 36.0 | 31.35 | 0.09364 | 0.09426 |
| 10.0 | 36 0 | 31.35 | 0.09364 | 0.09428 |
| 15.0 | 36 2 | 31.55 | 0.09426 | 0.09428 |
| 20 | 36.2 | 31.55 | 0.09426 | 0.09428 |
| 25 | 36.8 | 32.15 | 0.09602 | 0 09428 |
| 30 | 36.8 | 32.15 | 0.09602 | 0 09428 |
| 35 | 37.3 | 32 65 | 0.09754 | 0 09428 |
| 38 | 37 8 | 33 15 | 0.09904 | 0.09428 |
| 41 | 38.0 | 33 35 | 0.09963 | 0.09428 |
| 50 | 38 9 | 34.25 | 0.10231 | 0 09428 |
| 60 | 38.9 | 34.25 | 0.10231 | 0.09428 |
| 65 | 39.9 | 35 25 | 0 10529 | 0.09428 |
| 75 | 39.9 | 35.25 | 0.10529 | 0.09428 |
| 80 | 39.9 | 35.25 | 0.10529 | 0.09428 |

TABLE III. Sesame oil

Experimental conditions: Volume taken—35.5 c.c, temperature—30.35°C, initial level—3.4cm, degassed for 3 hours 30 mins.

$\alpha_0 = 0.12833$. $\lambda = 0.96$.

| Time interval mins. | Mercury level in manometer cm. | Length of mercury column cm. | Absorption per c c. $\alpha_{obs}$. c.c. | Absorption per c.c. $\alpha_{cal.}$ c c. |
|---|---|---|---|---|
| 2 | 30.8 | 27.4 | 0.11319 | 0 11319 |
| 5 | 34.7 | 31.3 | 0.1293 | 0.12829 |
| 13 | 34.7 | 31.3 | 0 1293 | 0.12899 |
| 23 | 34.3 | 30.9 | 0.1276 | 0 12899 |
| 33 | 34.3 | 30.9 | 0.1276 | 0.12899 |
| 43 | 34.3 | 30.9 | 0,1276 | 0.12899 |
| 53 | 34 3 | 30.9 | 0.1276 | 0.12899 |
| 60 | 34.3 | 30.9 | 0-1276 | 0.12892 |
| 73 | 34 9 | 31.5 | 0.1301 | 0.12899 |
| 83 | 34.4 | 31.0 | 0.1280 | 0 12899 |
| 93 | 34 3 | 30.9 | 0.1276 | 0.12899 |
| 108 | 33.8 | 30.4 | 0.1256 | 0.12899 |

TABLE IV. Linseed oil

Experimental conditions: Volume taken—36.7c.c, temperature—31.0°C, initial level—4.0 cm, degassed for 5 hours.

$\alpha_0 = 0.11740$ $\lambda = 1.0$

| Time interval minutes | Mercury level in manometer cm. | Length of mercury column cm | Absorption per c.c. $\alpha_{obs}$ c c. | Absorption per c.c. $\alpha_{cal.}$ c.c. |
|---|---|---|---|---|
| 2 | 29 5 | 25.5 | 0.10260 | 0 10151 |
| 5 | 33 4 | 29.4 | 0.11740 | 0 11661 |
| 12 | 33 4 | 29 4 | 0.11740 | 0.11740 |
| 17 | 33.4 | 29.4 | 0 11740 | 0.11740 |
| 21 | 33 4 | 29.4 | 0.11740 | 0.11740 |
| 41 | 33.4 | 29.4 | 0.11740 | 0 11740 |
| 56 | 33 4 | 29.4 | 0.11740 | 0.11740 |

TABLE V. Groundnut oil

Experimental Conditions: Volume taken—49.1c.c, temperature—25.4°C. initial level—4.0 cm, degassed for 4 hours.

$\alpha_0 = 0.08524$. $\lambda = 1.52$.

| Time interval | Mercury level in manometer | Length of mercury column | Absorption per c.c. | Absorption per c c. |
|---|---|---|---|---|
| minutes | cm. | cm. | $\alpha_{obs.}$ c.c | $\alpha_{cal.}$ c.c. |
| 5 | 31.0 | 27.0 | 0 08196 | 0.08209 |
| 10 | 32.0 | 28 0 | 0.08500 | 0.08512 |
| 15 | 32.0 | 28.0 | 0 0850 ) | 0 08524 |
| 20 | 32 0 | 28.0 | 0.08500 | 0.08524 |
| 25 | 32 0 | 28.0 | 0.08500 | 0.08524 |
| 35 | 32 4 | 28.4 | 0.08620 | 0 08524 |
| 40 | 32,4 | 28.4 | 0.08620 | 0 08524 |
| 45 | 32.4 | 28 4 | 0.08620 | 0 08524 |

## DISCUSSIONS

All the liquids under investigation showed a high rate of absorption within a period of 2-7 minutes from the beginning and then the rate slowed down. Over a long period of air absorption some of the characteristic curves show steady conditions for sometime while some others show variations. The variation of absorption within the period of observation can be accounted for by the fact that the net absorption processes, is the result of two different absorption factors *viz.*, the absorption of gas by the liquid and the evolution of gas from the liquid.

Now the association of gas and liquid molecules in the absorption process is maximum under a favourable condition when the liquid is said to be in equilibrium. But the absorption of gas is dependent on several factors, *viz.*, depth of liquid, free surface exposed to the gaseous medium, catalyst, if any, and the temperature. Since the process is a dynamic one and the temperature over a long period is difficult to control, the condition for a steady state is not easy to approach. Further there is the chance for the formation of volatile gases due to oxidation causing evolution of gas from the liquid. The electrostatic forces of attraction to form association of molecules in the absorption mechanism is sensitive to temperature variation of the system and consequently difficulty may arise for the accuracy of attaining an equilibrium condition. The identical nature of the curves indicate that the liquids under investigation are stable in character having high ordinates at the beginning. But if high ordinate is reached after sometime, *i.e.*, if the rate of absorption is slow at the

beginning, the liquid can be said to be unstable, for the slow process of attaining the high ordinate indicates that both the absorption and evolution of gas are going on simultaneously and the more gas is evolved the liquid becomes less stable.

From a study of the nature of the characteristic curves, it can well be represented empirically by an equation of the form

$$\alpha = \alpha_0 \ (1 - e^{-t/\lambda})$$

where $\alpha$ = absorption per c.c. in time $t$.
$\alpha_0$ = maximum absorption.
$t$ = time in minutes.
$\lambda$ = a coefficient, characteristic for a particular liquid.

For certain experimental conditions $\alpha_0$ is constant for a particular liquid, while $\lambda$, determining the quality of the liquid, is also a constant under that specified condition. The slope of the characteristic curves for a particular liquid is determined by the value of $\lambda$ which indicates the chemical condition of the liquid. So values of $\lambda$ for a liquid give information of the chemistry and degree of purification of the liquid under investigation. Solution of the above equation yields values of $\lambda$ and $\alpha_0$ for a particular liquid and the calculated values of $\alpha$ are in close agreement with the observed values as shown in the tables. The full line curve and the dotted one indicate the experimental and theoretical curves respectively (see figure 1). The discrepancy between the theoretical and

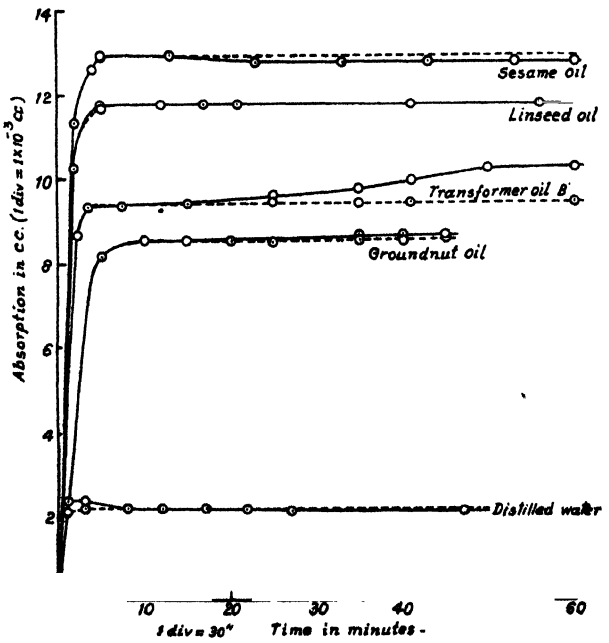


FIG. 1

experimental curves is attributable to varying experimental conditions within the period of observation, the rate of absorption is an exponential function of time. One notices from the graph that the absorption of dry air is low for distilled water while it is comparatively high for the oils. From the nature of the liquids it is evident that water is highly polar, while the oils being highly refined, the degree of polarity of the molecules is much low and dry air is non-polar in character. Since in the absorption mechanism some types of electrostatic forces come into play to form association of molecules, the degree of polarity of the molecules in the two phases influences the absorption process. So the nature of the absorption characteristic gives an idea of the degree of polarity of the molecules in the gas and also in the liquid and thus speaks in a qualitative way about the conditions of the liquid and the gas.

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